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(56) Documents Cited

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(58) Field of Search

UK CL (Edition P) H4D DPX DRPA DRPZ  
INT CL<sup>6</sup> G01S

(54) Abstract Title

Threat detection radar

(57) The apparatus is a multi-static radar which comprises a transmitter and a plurality of receivers which are mounted on a surface of an aircraft or tank in order to detect the proximity of an incoming threat, eg a missile, detect its position and velocity and generate an appropriate signal for a weapons command system for launching a munition to destroy the threat. When used on an aircraft, the environment is considered as uncluttered and therefore the signal generated consists of a combination of a chirp signal and a pure tone signal (figure 2), whereas in the cluttered environment, i.e. on the ground where trees and other obstructions could interfere, the transmitted signal solely consists of the pure tone signal (figure 3). The apparatus always includes a chirp generator and a pure tone generator. In the uncluttered case, received signals are processed and are passed to a time of flight measuring circuit and a Doppler shift measuring circuit which homodyne them with an output from the chirp generator and the pure tone generator circuit respectively. The resultant signals are passed to a signal processor which determines the position and velocity of the threat. In the cluttered environment, each receiver includes a high pass filter which passes only signals from the pure tone reflected signal that are Doppler shifted above a threshold. This removes all non-threat signals since they are unlikely to be moving fast enough to create a Doppler shift beyond the threshold.

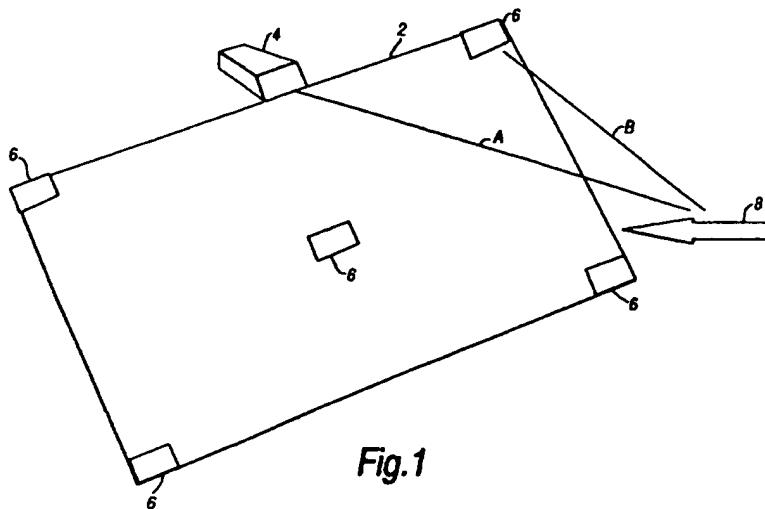
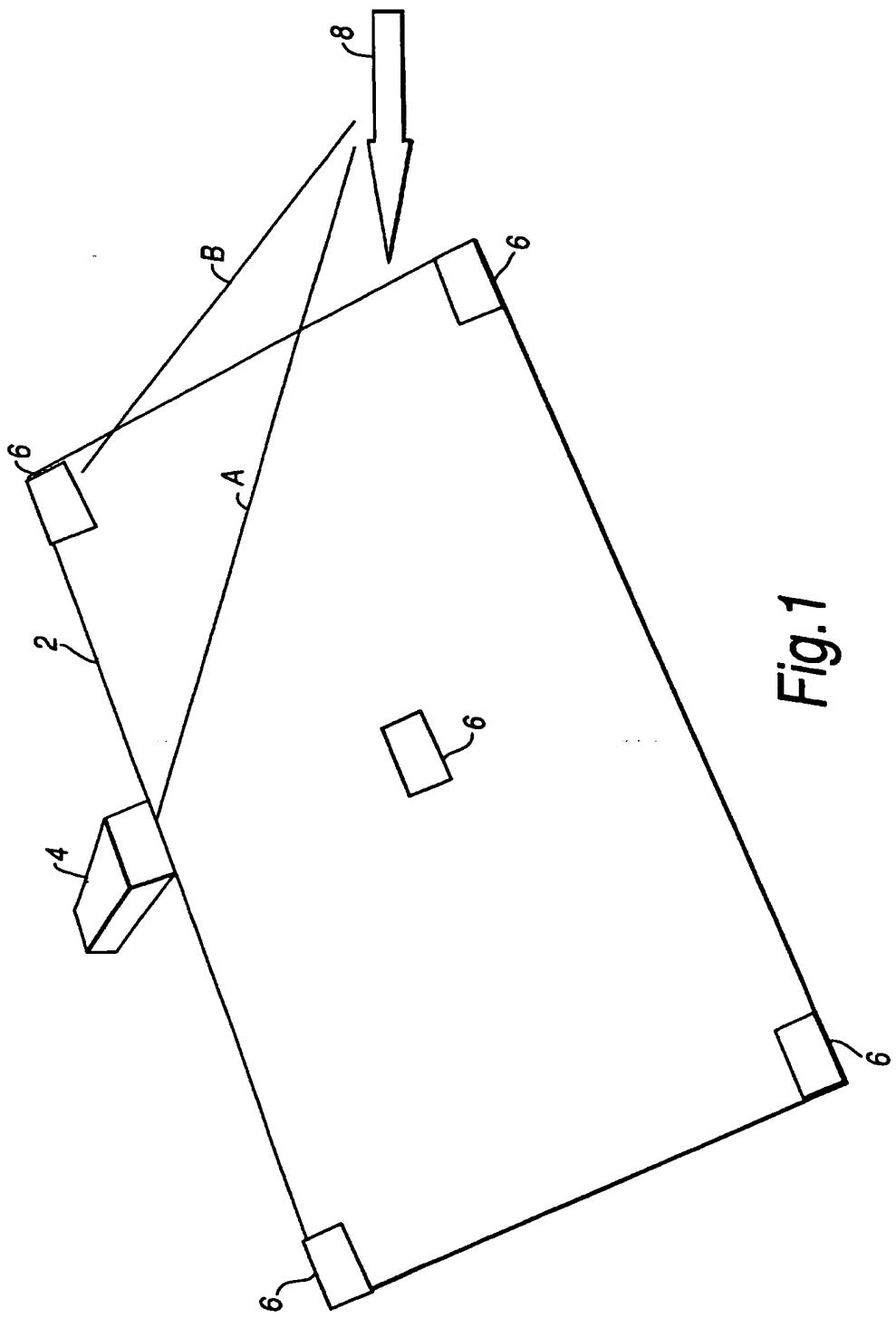


Fig.1

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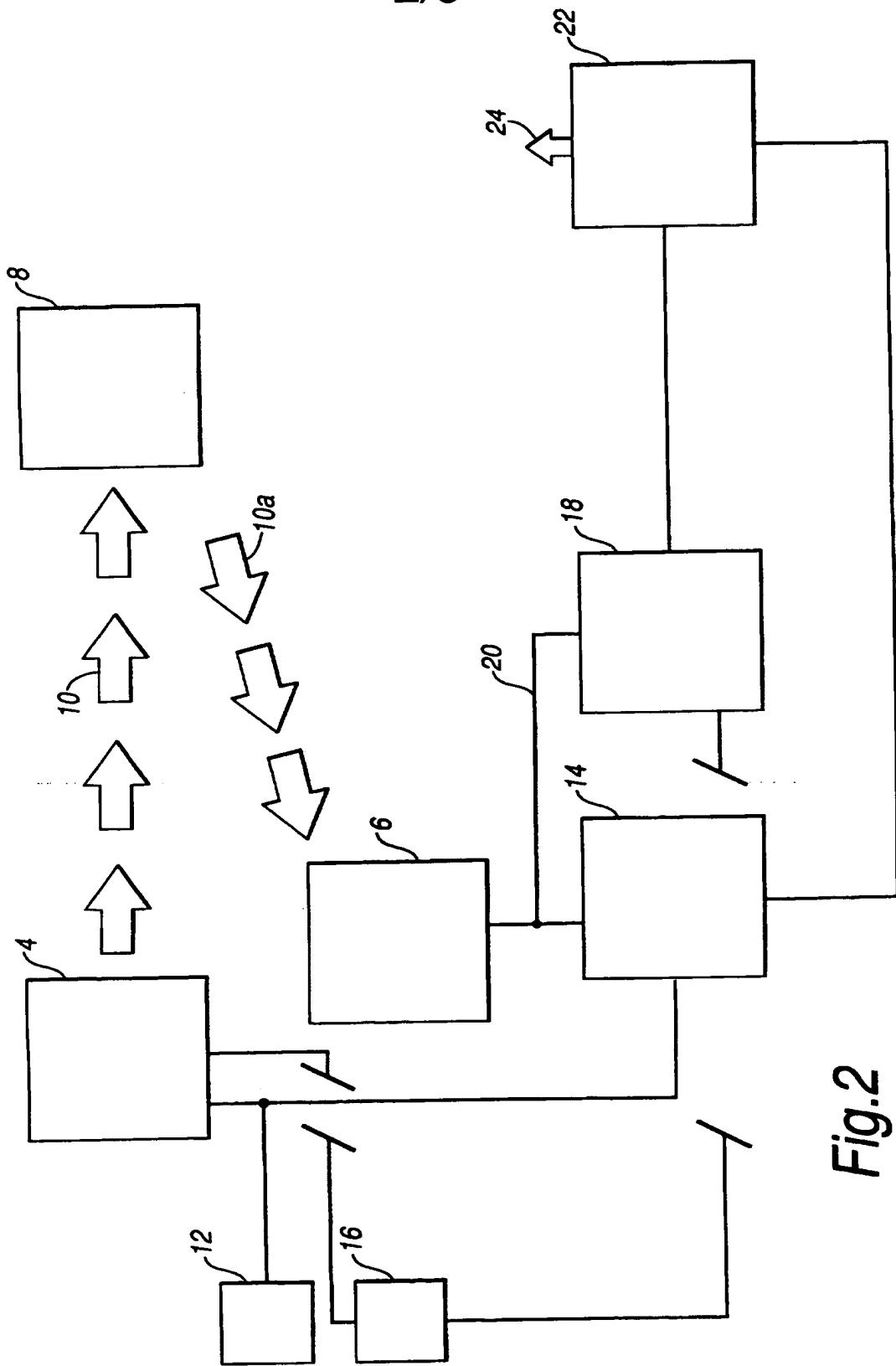


Fig.2

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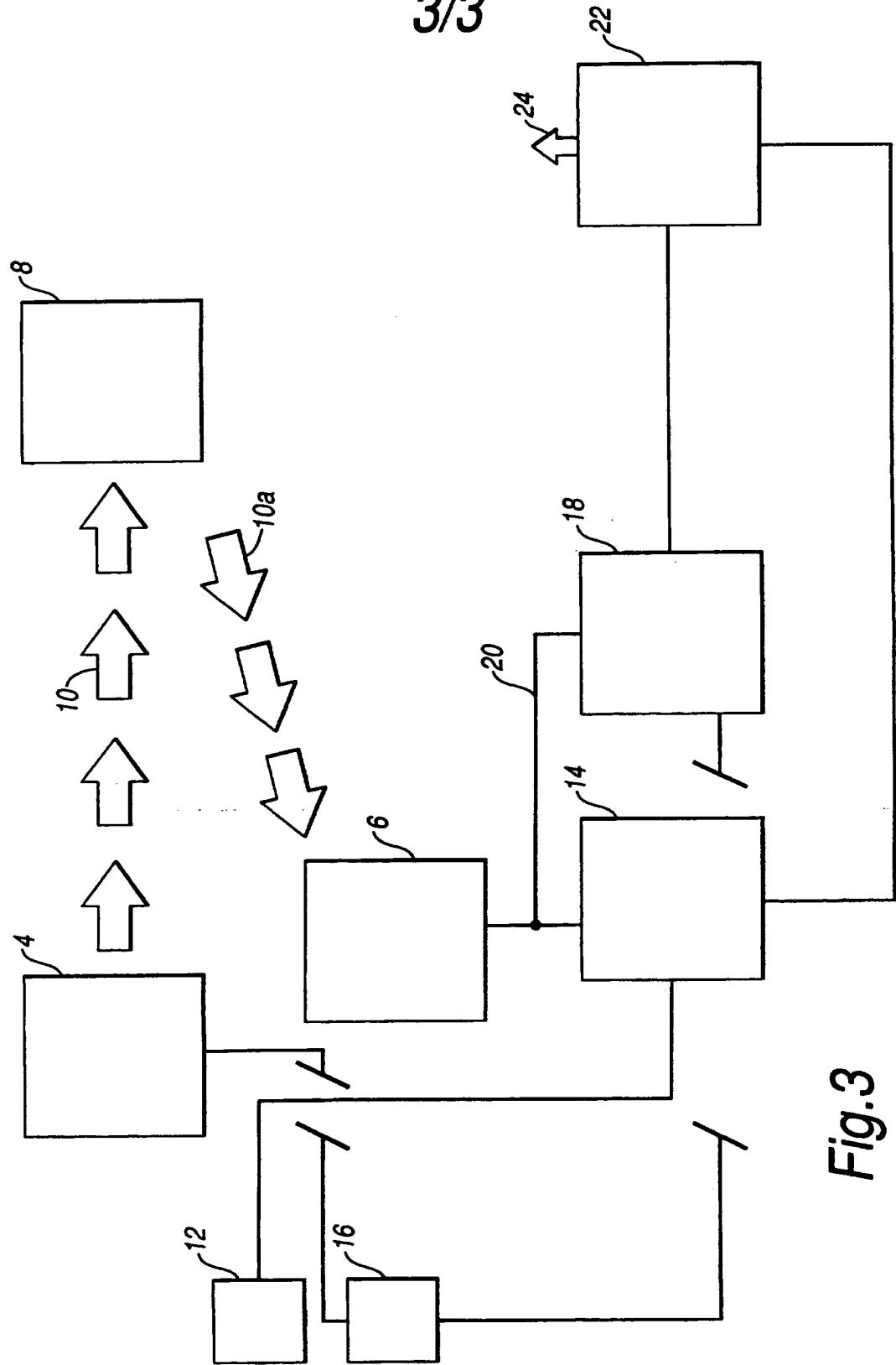


Fig. 3

## THREAT DETECTION APPARATUS

The present invention relates to threat detection apparatus, and more specifically it relates to detecting the presence of a missile in close proximity to its target, which may be for example, a tank or an aeroplane.

In a battlefield situation, it is advantageous to be able to identify when a missile is a threat to a particular piece of military hardware, such as a tank or aeroplane. In this way, once a missile is detected as a threat the tank or aeroplane can take defensive action by firing a munition at the missile in order to destroy it before the missile reaches its target. In this way, effective use of munitions is achieved because the defensive action is only taken when the detected missile is deemed to be a threat when in very close proximity to the missile target.

An aim of the present invention is to provide apparatus for detecting the above mentioned threat.

According to the present invention, there is provided threat detection apparatus comprising a transmitter and a plurality of receivers and a signal processing circuit, said receivers being distributed about an area to define the area to be protected from the threat, characterised in that said signal processing circuit includes the transmitter which is arranged to transmit a radio frequency signal in the direction of the threat, and the plurality of receivers are arranged for receiving a reflected radio signals from the threat, said signal processing circuit further including means for measuring the time taken for the radio signal to reach the threat and the time taken for the reflected signal to be received by each of the plurality of receivers, means for measuring the Doppler shift detected in the radio frequency signal, and processing means arranged to receive the signals generated by the time measuring circuit

and Doppler shift measuring circuit to provide position and velocity data of the detected threat.

The signal processing circuit may include a chirp generator circuit and a pure tone generator circuit, and the transmitter is arranged to generate radio frequency signal which is a combination of the chirp signal and the pure tone signal.

The signal processing circuit may include a chirp generator circuit and a pure tone generator circuit and the transmitter is arranged to generate a radio frequency signal which consists solely of the pure tone signal, and each receiver further includes a high pass filter.

Each receiver has an output connected to a respective time of flight measuring circuit and a Doppler shift measuring circuit, said time of flight measuring circuit further receives an output from the chirp generator, and said Doppler shift measuring circuit further receives a sampled output from the pure tone generator, and respectively produce a time of flight signal and a Doppler shifted signal which is passed to the signal processing circuit which is arranged to receive signals from all the receivers and combine those signals to generate data indicative of the position and velocity of the threat.

The output of the signal processing circuit may be used to control a weapon system for launching a munition to destroy the threat.

The transmitter and receivers may be deployed about an outer surface of an aeroplane or tank.

Embodiments of the present invention will now be described with reference to the accompanying drawings, wherein,

FIGURE 1 shows a conceptual diagram of a piece of military hardware having a transmitter mounted thereon and a plurality of receivers,

FIGURE 2 shows a block diagram of a signal processing circuit for use by the military hardware in an uncluttered environment, and,

FIGURE 3 shows a block diagram of a signal processing circuit used by the military hardware in a cluttered environment.

Referring to Figure 1, there is shown a tank 2, having mounted thereon a transmitter 4, and a plurality of receivers 6. The receivers may be placed anywhere on the tank but conveniently they may be placed as shown in close proximity to the four corners of the tank and one at the centre of the tank. Figure 1 also shows a threat in the form of a missile 8, approaching the tank and in close proximity thereto. The detection apparatus comprises the transmitter and the receivers, together with the signal processing circuit which will be described in detail with reference to Figures 2 and 3.

The transmitter 4 transmits a signal which radiates in all directions away from the tank and is shown travelling a distance A towards the target. The signal is reflected back to the target to one or more of the receivers and in so doing travels a distance B. The total distance travelled by the signal is A + B.

Referring to Figure 2, there is shown a block diagram of a signal processing circuit which is used in an uncluttered environment. An uncluttered environment would be for example, the sky, and therefore, this circuit is eminently suitable for defending an aircraft.

The signal processing circuit comprises the transmitter 4, and the plurality of receivers 6 of which one is shown. The target is shown

designated 8, and the radio signals 10, are transmitted from the transmitter to the target and the signals 10a are reflected back to the plurality of receivers 6. The circuit also comprises a chirp generator 12 which is connected to the transmitter and to a time of flight measuring circuit 14. A pure tone generator 16 is also connected to the transmitter and is connected to a Doppler shift measuring circuit 18. The time of flight measuring circuit 14 and the Doppler shift measuring circuit 18 also receives the output signal from the receivers via lines 20. An output from the time of flight measuring circuit 14, and an output from the Doppler shift measuring circuit 18 is connected to a digital signal processor 22, which is suitably programmed to combine the position and velocity data and generate an appropriate output signal on line 24 to command and control a weapon system for firing a munition to destroy the incoming target 8.

The transmitter 4 is arranged to mix the chirp signal generated by the chirp generator 12 and the pure tone signal generated by the pure tone generator 16, and transmit the mixed signal to the target 8. The chirp signal is used for time measurement, and the pure tone signal is used for Doppler shift measurement.

The time of flight measuring circuit 14, mixes the received chirp signal from the target 8 with a sampled chirp signal from the transmitter circuit 4. The resulting signal is the difference between the instantaneous frequencies in each component and is a measure of the time delay between the transmission and reception, and will be recognised as a standard frequency modulator continuous wave (FMCW) radar technique.

Each receiver 6 is connected to its own time of flight measuring circuit 14 and Doppler shift measuring circuit 18, which together produce a value for the total distance travelled by the radio signals which includes the distance from the transmitter to the target (distance A) plus the distance from the target to the receiver in question (distance B). There is no unique solution of the relative values of A or B, just a locus with total distance A + B, which is in fact, an elliptical surface of revolution.

With several receivers in use, each producing a possible measure of the target positions described by a surface, by combining several receivers solutions a unique position of the target 8 may be determined from the single point which is the intersection of all the elliptical surfaces. Implementation of this may be achieved by matrix methods working on the digitised values of time delay. This is similar to the technique known as multilateration.

The pure tone part of the signal received is used by a mixer it with a pure tone part of the transmitted signal. The difference in frequency is a measure of the velocity components relative to the transmitter and the receiver. By combining several Doppler velocity measurements from the various receivers, it is possible to define the velocity vector of the target in the space relative to the frame of reference of the centre. The implementation is a digitised method where a matrix method is used to combine the Doppler velocity measurements of several receivers. The algorithm for this requires the position of the target, obtained as described previously.

Referring to Figure 3, there is shown a signal processing circuit which may be used in a cluttered environment. A cluttered environment

would be a ground environment whereby interference may be generated by surrounding structures, such as buildings or trees, and this circuit is eminently suitable for defending a tank in such environments.

It will be seen that the circuit is very similar to that of Figure 2 and like components have been given the same numerical designation.

The only difference between the two circuits is that the output of the chirp generator 12 is not connected to the transmitter 4 and therefore the output of the transmitter 4 consists of solely pure tone signals, which are generated by the pure tone generator 16. This has been done since other non-threat targets will produce ambiguity and clutter into the solution. This makes each of the elliptical volumes of revolution transform into hollow spheroids of indeterminate thickness and so prevents localisation of the threat.

To operate in the cluttered environment, the Doppler shifted return from the threat 8 is used to discriminate from the background. To achieve this a filter circuit is included in the receiver amplifier circuit 6. The filter circuit is activated such that it only allows a signal from the pure tone reflected signal that is Doppler shifted above a threshold limit. Therefore, all non-threat signals are removed from this filtered signal since they are unlikely to be moving fast enough to create the Doppler shifted signal beyond the threshold.

Position fixing the target 8 is achieved by using the return signal and using it to trigger a threshold circuit that cuts off the flow of the internal chirp signal to the digital signal processor 22. The chirp signal is mixed with the pure tone signal to obtain an IF signal suitable for digitisation. When the chirp signal is cut off, the IF signal ends. The processor 22 calculates the frequency spread of the IF signal resulting

from the mixing of the pure tone and the chirp and cut off point/frequency represents the time taken for the transmitted signal to go from the transmitter 4 to the target 8, plus the time taken for it to go from the target 8 to the receiver 6 ( $A + B$ ). Therefore a set of such distance measurement are provided by the plurality of receivers 6. The multilateration algorithm is then used to determine the position of the target, and the Doppler shifted signals can be used to determine the velocity of the threat.

The output signal on line 24 generated by the signal processing circuit 22 is used to control a weapon system to destroy the threat.

## CLAIMS

1. Threat detection apparatus comprising a transmitter and a plurality of receivers and a signal processing circuit, said receivers being distributed about an area to define the area to be protected from the threat, characterised in that said signal processing circuit includes the transmitter which is arranged to transmit a radio frequency signal in the direction of the threat, and the plurality of receivers are arranged for receiving a reflected radio signals from the threat, said signal processing circuit further including means for measuring the time taken for the radio signal to reach the threat and the time taken for the reflected signal to be received by each of the plurality of receivers, means for measuring the Doppler shift detected in the radio frequency signal, and processing means arranged to receive the signals generated by the time measuring circuit and Doppler shift measuring circuit to provide position and velocity data of the detected threat.
2. Threat detection apparatus as claimed in Claim 1, wherein the signal processing circuit includes a chirp generator circuit and a pure tone generator circuit, and the transmitter is arranged to generate radio frequency signal which is a combination of the chirp signal and the pure tone signal.
3. Threat detection apparatus as claimed in Claim 1, wherein the signal processing circuit includes a chirp generator circuit and a pure tone generator circuit and the transmitter is arranged to generate a radio frequency signal which consists solely of the pure tone signal.

4. Threat detection apparatus as claimed in Claim 3, wherein each receiver further includes a high pass filter.
5. Threat detection apparatus, as claimed in any preceding Claim, wherein each receiver has an output connected to a respective time of flight measuring circuit and a Doppler shift measuring circuit, said time of flight measuring circuit further receives an output from the chirp generator, and said Doppler shift measuring circuit further receives a sampled output from the pure tone generator, and respectively produce a time of flight signal and a Doppler shifted signal which is passed to the signal processing circuit which is arranged to receive signals from all the receivers and combine those signals to generate data indicative of the position and velocity of the threat.
6. Threat detection apparatus as claimed in any preceding Claim, wherein the output of the signal processing circuit is used to control a weapon system for launching a munition to destroy the detected threat.
7. Threat detection apparatus as claimed in any preceding Claim, wherein transmitter and receivers are deployed about a surface of an aircraft.
8. Threat detection apparatus as claimed in any preceding Claims 1 to 6, wherein the transmitter and receivers are deployed about a surface of a tank.

**9. Threat detection apparatus substantially as hereinbefore described  
with reference to the accompanying drawings.**



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Application No: GB 9800756.0  
Claims searched: 1 at least

Examiner: Dr E P Plummer  
Date of search: 13 July 1998

**Patents Act 1977**  
**Search Report under Section 17**

**Databases searched:**

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.P): H4D (DRPA, DRPZ, DPX)

Int Cl (Ed.6): G01S

Other:

**Documents considered to be relevant:**

Category	Identity of document and relevant passage	Relevant to claims
A	GB2251351A BRITISH AEROSPACE whole document	
X	EP0777133A1 DENSO CORP whole document	1,5,8
X	WO97/14058A1 CAMBRIDGE CONSULTANTS whole document	1,6
X	WO95/15501A1 WURMAN whole document	1
X	WO90/13048A1 CAMBRIDGE CONSULTANTS whole document	1,7
X	US4994809 HUGHES whole document	1,8
X	US4746924 BOEING whole document	1,6,7
X	US4499468 USA whole document	1

X Document indicating lack of novelty or inventive step  
Y Document indicating lack of inventive step if combined with one or more other documents of same category.

& Member of the same patent family

A Document indicating technological background and/or state of the art.  
P Document published on or after the declared priority date but before the filing date of this invention.  
E Patent document published on or after, but with priority date earlier than, the filing date of this application.



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Application No: GB 9800756.0  
Claims searched: 1 at least

Examiner: Dr E P Plummer  
Date of search: 13 July 1998

Category	Identity of document and relevant passage	Relevant to claims
X	US4318102 USA whole document	1
A	International Defence Review 7/1993 page 584: U Ivarsson: Multistatic radars promise stealth detection	
X	IEEE Transactions on Aerospace and Electronic Systems vol. AES-19 no. 6 November 1983 pages 831-839: RC Heimiller et al: Distributed Array Radar.	1,6,7

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
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&	Member of the same patent family	E	Patent document published on or after, but with priority date earlier than, the filing date of this application.